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POTENTIAL FOR SEAGRASS RESTORATION IN GALVESTON BAY, TEXAS

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Abstract.—Seagrass meadows were lost from West Bay, part of the Galveston Bay system, between 1956 and 1982 due apparently to acute and chronic effects of waterfront development and water quality degradation. Various transplanting methods and materials were used to determine whether *Halodule wrightii* and *Ruppia maritima* could be restored to the area since environmental conditions have improved. Plugs of *Halodule* in peat pots survived better than did bare root transplants. Faunal exclusion cages aided survival and growth of those transplants, but only when mesh size was small enough (< 3 cm) to block small fishes and decapods typical of West Bay that were observed to disturb transplants. Cages need to protect transplants 60-90 days to be effective. Enclosing propagules in cheesecloth bags may be more useful and less time-consuming than using plugs, more so for faster-growing *Ruppia* than for slower-growing *Halodule*. There were no indications that planting on 0.5 m vs. 1.0 m centers or in square vs. rectangular beds produced better survival. *Halodule* transplanted in peat pots on 0.5 m centers was able to survive over two years after removal of small mesh cages. Transplanting *Halodule* was effective only during April-August, but *Ruppia* grew quickly and produced seeds within 47 days after planting in September. Mixed transplants of *Ruppia* and *Halodule* could be advantageous, as the annual *Ruppia* is able to spread rapidly and stabilize a transplant site whereas the perennial *Halodule* spreads more slowly but becomes the dominant species over time. In the future, seagrasses can be transplanted successfully into western Galveston Bay if certain precautions are taken to insure survival and growth.

Seagrasses provide food and shelter for juveniles and adults of many commercially and recreationally important species of fish and shellfish and their forage organisms (Fonseca 1989; Zieman & Zieman 1989). As a result, they often support faunal densities much greater than those found in adjacent sand or mud habitats. Seagrass meadows are a sensitive habitat and are adversely affected by such factors as industrial and agricultural run-off, eutrophication, dredging, increased turbidity, bioturbation, storm-associated scour, and subsidence (Zieman & Zieman 1989; Fonseca 1992). Such factors have caused a decline in acreage of this valuable habitat along the margins of the northern Gulf of Mexico by 30-80% over the past four decades (Duke & Kruczynski 1992).

Seagrass acreage in the western arm of Galveston Bay, Texas, declined from 458 ha in 1956 to 0 by 1987 (Pulich & White 1991). Most of these seagrass meadows (primarily shoalgrass *Halodule wrightii*) grew along the barrier island edges of western West Bay. The only seagrass beds remaining in this estuary grow in Christmas Bay, a semi-isolated embayment southwest of West Bay, although acreage has declined there as well; 502 ha in 1971-72 versus 113 ha in 1987 (Adair et al. 1994). Seagrass loss was attributed primarily to waterfront dredging, spoil placement on seagrass beds, and subsequent increases in turbidity, sedimentation and erosion in West Bay (Pulich & White 1991). Secondary causes included overwash from Hurricane Carla in 1961 and increased turbidity and algal blooms after the 1950's drought ended. Point source pollution was suggested as an alternative stressor (Adair et al. 1994), but a previous assessment of water and sediment quality has indicated few pollutant impacts in West Bay (Ward & Armstrong 1992).

Seagrass restoration now seems possible in areas that once supported lush beds. Water clarity has improved since the 1960s (Ward & Armstrong 1992). Turbidity and salinity in West Bay are now similar to those in Christmas Bay (Pulich & White 1991). Waterfront dredging has declined since the period of maximum seagrass loss (prior to 1979), and upland placement of maintenance dredge materials from canal housing developments is now required (J. Boslet, U. S. Army Corps of Engineers, Galveston District, pers. comm.). Natural recolonization by *Halodule* may now be prevented by lack of a nearby propagule or seed source (these are unlikely to escape through the narrow passes from Christmas Bay except during extreme tides). Successful restoration of seagrass beds should increase habitat for forage organisms and fisheries species such as penaeid shrimps *Penaeus* spp. and spotted seatrout *Cynoscion nebulosus* (cf. Zieman & Zieman 1989).

The goal of this project was to determine whether restoration of viable *Halodule* habitat to its former range in West Bay is possible. The objective was to assess factors associated with transplant methodology that could affect survival and growth of transplanted seagrass. Field and laboratory experiments and qualitative observations were conducted to determine whether *Halodule* and the salt-tolerant, freshwater wigeongrass *Ruppia maritima* (spelling of common name follows Kantrud 1991) would survive and grow using various construction materials and transplant methods suggested by Fonseca (1994).

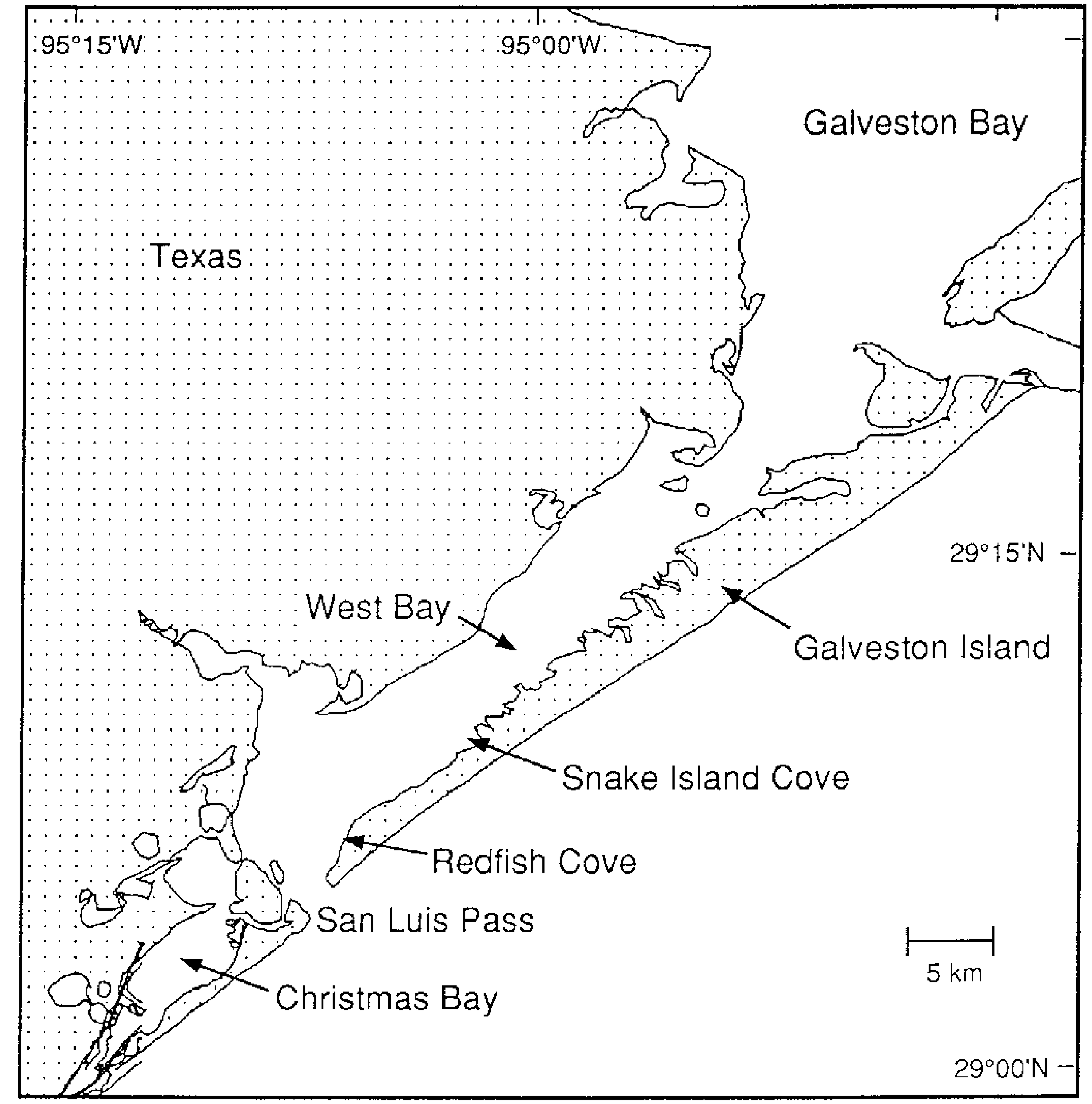

Figure 1. Experimental and natural seagrass sites in West Bay, part of the Galveston Bay estuary.

Methods and Materials

Potential restoration sites were chosen from historical photographs and actual 1993 conditions. Aerial photographs from the Texas Natural Resources Information System archives and from the Texas Parks and Wildlife Department, Resource Protection Division, for the years 1930, 1956, 1965, 1975, 1982, 1987, and 1989 were examined. In November 1930 and in August 1956, seagrasses grew along the southeastern bay shore in a band of varying width (100-400 m at widest points) and density from San Luis Pass on the western tip of Galveston Island eastward approximately 12 km to Snake Island Cove (Fig. 1). Seagrasses became patchy and extended perhaps another 5 km eastward of Snake Island

Cove. By October 1965, seagrass beds had thinned out in general and had disappeared from areas adjacent to canal housing developments on western Galveston Island. By October 1975, seagrasses had become restricted to narrow beds on the western tip of the island. No seagrasses were detected along Galveston Island in 1982, 1987, or 1989 photographs, although seagrasses remained visible in Christmas Bay (Fig. 1). This historical distribution led to selection of two experimental sites: Redfish Cove (29° 09' N, 95° 02' W) because it was the last area to harbor seagrasses, and Snake Island Cove (29° 05' N, 95° 07' W) because it is an embayment protected by an offshore bar (Fig. 1).

Sediment samples (top 5 cm) were collected at these two sites and near both ends of the southeastern Christmas Bay seagrass bed in February 1993 to compare sediment organic content (Dean 1974) and particle size (Folk 1974). Turbidity samples were collected in February and March 1993 and analyzed with an HF Scientific DRT 100B Turbidimeter. There were no appreciable differences in sediments among the sites (organic content: 0.69-0.92%; sand: 81-89%; silt: 3-6%; clay: 8-13%). Turbidity was higher in Christmas Bay (26-62 NTU) than at either experimental site (7-18 NTU).

Halodule used in transplant experiments was collected from Christmas Bay. *Ruppia* was obtained from Gangs Bayou, 15 km east of Snake Island Cove, although it was occasionally mixed with *Halodule* in Christmas Bay samples.

Experiment 1: Bed configuration.—Experimental seagrass beds were constructed at Redfish Cove and Snake Island Cove to assess effects of bed shape and density of transplants on survival and growth. Bed shape was either 3 m by 3 m or 2 m by 10 m, and transplant density was either 0.5 m or 1.0 m centers. One bed of each shape and density was constructed at each site. Each bed was surrounded with 1.2 m high, 5 cm mesh, galvanized chicken wire fencing to deflect large fishes and decapods that could disturb transplants (Fonseca 1994). Experimental beds were located at depths similar to those in Christmas Bay (approximately 1 m during spring high tides).

Transplanting units (TPUs) of *Halodule* were collected on 19-20 April 1993 after the seagrass leaves had developed sufficiently, following the methods of Fonseca (1994). A 7.5 cm diameter circular sod plugger was used to extract TPUs from the donor bed. Each TPU was then inserted directly into a 7.5 cm diameter peat pot. TPUs were transported in a seawater-filled holding tank and covered with wet burlap to prevent desiccation. Once at the transplant site, the sod plugger was used to create holes into which TPUs were placed, after ripping the sides of the peat pots to allow rhizome spread. Periodic visits were made to both sites to insure that fencing was intact around each transplant bed. All TPUs were examined by snorkeling over the beds on 25 June 1993 (66 days post-transplant) and on 23 and 26 July 1993 (94-97 days post-transplant). On 7 July 1993, all chicken wire fence was removed (due to rusting) and replaced with plastic safety fence (3.8 cm mesh), but no observations were made of the plants. Percent survival was assessed with one-way analysis of variance (*ANOVA*) of the four combinations of planting density and bed shape.

Experiment 2: Faunal exclusion cages and transplant methods.—Bioturbation and herbivory can contribute to transplant failure as much as the choice of transplant method (Fonseca 1994). A second restoration experiment, testing faunal exclusion cages of four mesh sizes and two transplant methods, was conducted at Redfish Cove during 6 August - 18 November 1993. Submerged exclusion cages (1.5 m by 1.5 m by 0.25 m high) were designed with skirts to keep fishes and invertebrates from entering beneath fencing at the sediment surface and with lids to enable access during the experiment. Cage walls and lids were constructed of four different materials with varying mesh sizes: galvanized hardware cloth (1.3 cm), vinyl-covered hardware cloth (2.5 cm), plastic safety fence (3.8 cm), and galvanized chicken wire (5.0 cm). Exclusion cages were placed in two rows of 12 cages each, parallel to and approximately 30 m from the shoreline in < 1 m depths, adjacent to the Experiment 1 site. Six cages of each mesh size were constructed, with three cages of each mesh size allotted to test one of two transplanting methods.

Two methods of transplanting were tested, bare roots and peat pots (reviewed by Fonseca 1994). A 7.5 cm diameter sod plugger was used to extract all *Halodule*, ensuring that TPU biomasses were approximately equal. To create the bare root TPUs, *Halodule* was washed of surrounding sediments and attached to U-shaped staples (fashioned from 20 cm lengths of 16 gauge aluminum wire) with paper-covered twist ties. A dive knife was used to dig holes into which bare root TPUs were placed, with the staple bridge just under the sediment surface. Peat pot TPUs were transplanted as described previously. Each cage received nine TPUs planted on 0.5 m centers.

Lids were attached to the cages after transplanting. Cages and TPUs were monitored at 13, 21, 35, 48, 63 and 104 days post-transplanting (ending 18 November 1993). All TPUs were accounted for by removing lids, manually locating each TPU, and categorizing each by *Halodule* appearance as healthy (lush, long shoots), unhealthy (sparse, short shoots), or absent. These subjective observations were assigned numerical values of 2, 1, and 0, respectively, and mean values for each cage were derived for each sampling date. *Halodule* health on each date was tested with two-way analysis of variance (*ANOVA*) of the cage means for effects of planting method and cage mesh size. Comparison of treatment means for significant main effects employed Ryan's Q test (Day & Quinn 1989).

Qualitative observations of the potential effects of bioturbators or herbivores were collected during the same time period from transplants installed in an outdoor fiberglass tank receiving flowing seawater at the National Marine Fisheries Service Galveston Laboratory. Sediment from Redfish Cove was placed in the tank to a depth of 10 cm. The circular tank (1.8 m diameter) was partitioned into four equal sections with 2.5 cm mesh vinyl-coated hardware cloth. Water depth was maintained at 23-27 cm and flow was set for one turnover in tank volume per day. Fifteen peat pot TPUs of mixed *Halodule* and *Ruppia* were placed in each section on 20 September 1993. Eight additional TPUs were sieved to remove sediments and refrigerated to measure pre-transplant characteristics. Each section of the tank received one of three species of organisms with potential for site disturbance that were commonly seen at the transplant sites: thinstripe hermit crab *Clibanarius vittatus*, blue crab *Callinectes sapidus*, and pinfish *Lagodon rhomboides*. Crabs have been cited as bioturbators by Fonseca (1994), and both *Callinectes* and *Lagodon* consume plant material (Stoner 1980; Laughlin 1982). Densities were 12 *Clibanarius* (2-5 cm shell diameter), four *Callinectes* (5-10 cm carapace width), or four *Lagodon* (5-8 cm total length) per section. The fourth section was kept free of animals. *Clibanarius* and *Lagodon* were introduced on 22 September, and *Callinectes* was introduced on 30 September. Caged animals were fed frozen shrimp on Monday, Wednesday, and Friday of each week. Periodic observations were made of organism behavior.

The tank was drained on 22 October 1993. TPUs were dug up, peat

pots were removed, and seagrasses were sieved to remove sediments. Each TPU, including the pre-transplant TPUs, was separated into aboveground and belowground biomass. Leaves were counted and length measurements of 10 randomly selected leaves per TPU were recorded. All samples were soaked in 10% phosphoric acid to remove calcification, rinsed, and dried at 85-100°C for 24 hr. Seagrass leaf count, leaf length, and aboveground and belowground biomasses were noted.

Experiment 3: Halodule versus Ruppia, peat pots versus cheesecloth bags.—Survival and growth of *Halodule* and *Ruppia* were compared using peat pot and cheesecloth bag TPUs in an outdoor fiberglass tank receiving flowing seawater. Durako et al. (1993) suggested the cheesecloth bag method as an alternative to diver-oriented transplant methods because it may be less time-consuming. *Ruppia* was used to assess whether mixed transplants would affect overall success of transplant beds. The rectangular tank (6.1 m by 1.8 m by 0.8 m high) received water and sediment as described previously. A 7.5 cm diameter sod plugger was used to collect TPUs in order to keep all biomasses similar. Cheesecloth bags were 1-ply, 15 cm by 15 cm, and sewn on three sides with cotton thread. Quarry rocks were sewn into the corners to weight the bags down. After plant material was inserted into the bag, the open side was sewn shut and the bags were placed in buckets of seawater. Peat pot TPUs were prepared as described previously. Sixty TPUs (15 of each type) were placed in the tank on 0.25 m centers in 15 parallel rows of four TPUs each. One TPU of each type was set randomly in each row. A sod plugger was used in planting peat pots, whereas cheesecloth bags were placed directly on the sediment surface.

TPUs were planted on 20 September 1993, and growth of rhizomes from TPUs was measured after 25, 33, and 47 days. Coverage was estimated by measuring seagrass spread in four directions. The longest rhizome from each TPU was measured first, then three other measurements were taken at 90°, 180° and 270° from the first measurement. Actual rhizome length measurements (mm) were recorded for each TPU after 25 and 33 days and were used to determine growth rates for the four types of TPUs. After 47 days, TPUs had begun to coalesce and it was no longer possible to determine the source TPU for many rhizomes. The shortest distance between edges of two TPUs was 235 mm; therefore, 112.5 mm was established as the maximum rhizome length before potentially crossing another rhizome.

Table 1. Analysis of variance (*ANOVA*) comparisons of *Halodule wrightii* health relative to planting method and mesh size of faunal exclusion cage at six intervals after transplanting on 6 August 1993. Mean health of nine transplant units (TPU) per cage was used as the observation. N = 3 per combination of method and cage mesh. *ANOVA* df = 7 (Model), 1 (Method), 3 (Cage mesh), and 16 (Error).

Source	MS	*F*	*P*	MS	*F*	*P*
	Day 13			Day 21		
Model	0.263	3.22	0.025	0.628	6.72	0.008
Method (M)	0.700	8.58	0.010	2.600	27.86	0.001
Cage mesh (C)	0.355	4.35	0.020	0.498	5.34	0.010
M x C	0.026	0.32	0.812	0.099	1.06	0.392
Error	0.082			0.093		
	Day 35			Day 48		
Model	0.975	10.73	0.001	0.972	12.68	0.001
Method (M)	3.227	35.52	0.001	3.300	43.05	0.001
Cage mesh (C)	1.007	11.09	0.001	0.899	11.73	0.001
M x C	0.192	2.12	0.138	0.268	3.50	0.040
Error	0.091			0.077		
	Day 63			Day 104		
Model	1.070	10.19	0.001	0.614	3.82	0.013
Method (M)	3.450	32.86	0.001	1.550	9.64	0.007
Cage mesh (C)	0.865	8.24	0.002	0.583	3.62	0.036
M x C	0.482	4.59	0.017	0.333	2.07	0.145
Error	0.105			0.161		

Length of each of the four measured rhizomes was used as an indicator of coverage in each quadrant around a TPU. The four measurements were added to estimate coverage for the whole TPU area, with a total of 450 mm equal to 100% coverage. Mean percent coverage was calculated for each type of TPU and each observation date, and these means were used to estimate coverage rates for each type of TPU. Differences in rhizome length and percent coverage (arcsine transformed) were tested with one-way *ANOVA*. Comparison of treatment means employed either the GT2 test for unbalanced designs (rhizome length; Day & Quinn 1989) or Ryan's Q test for balanced designs (coverage).

RESULTS

Experiment 1: Bed configuration.—Survival of peat pot TPUs planted on 20 April 1993 was 65% in Redfish Cove and 67% in Snake Island Cove 66 days after transplanting. There were no significant differences in mean *Halodule* survival among the four combinations of bed shape and planting density, but replication of each bed configuration was minimal (n = 2) and thus provided low power.

Redfish Cove was revisited on 23 July 1993 (94 days after transplanting), and there was almost no live *Halodule* present. Only two of the original 142 TPUs contained any *Halodule*, and these contained only a few short shoots. Four bare TPUs were removed and none contained any live roots or rhizomes. Snake Island Cove was revisited three days later, and none of the 142 TPUs had survived. Two bare TPUs were examined and contained some root material, but three additional TPUs contained no live roots or rhizomes. Neither of these beds exhibited any growth in 1994.

Experiment 2: Faunal exclusion cages and transplant methods.—Failure of the Experiment 1 transplants may have been due to transplant method or to the presence of bioturbators that gained access through screens of relatively large mesh (safety fence and chicken wire). Analyses of *Halodule* health and survival in relation to peat pot versus bare root transplant methods and to faunal exclusion cages of four mesh sizes were made on six observation dates over 104 days (6 August - 18 November 1993). Health of *Halodule* TPUs was significantly affected by both planting method and cage mesh size on all observation dates (Table 1). Mean *Halodule* health declined over time for both peat pot and bare root TPUs, in part due to inclusion of typical fall senescence into the test period. However, health of peat pot TPUs was always significantly better than that of bare root TPUs (Fig. 2), and health in safety mesh cages (3.8 cm) was always significantly lower than in other mesh sizes (Fig. 3). There were no significant differences in *Halodule* health among other mesh sizes except on the last observation date. After 104 days, the relatively healthy TPUs in chicken wire cages (5.0 cm mesh) were found to be in poor condition (Fig. 3). On the last observation date, only peat pot TPUs protected by 1.3 cm and 2.5 cm cages appeared healthy enough to overwinter. Three peat pot TPU beds that had survived unprotected for two years were found in December 1995, but cage mesh size could not be determined.

Inclusion of common estuarine fauna in an outdoor tank with transplanted *Halodule* resulted in alterations to some floral characteristics. After approximately 30 days in the tank sector free of organisms, leaves

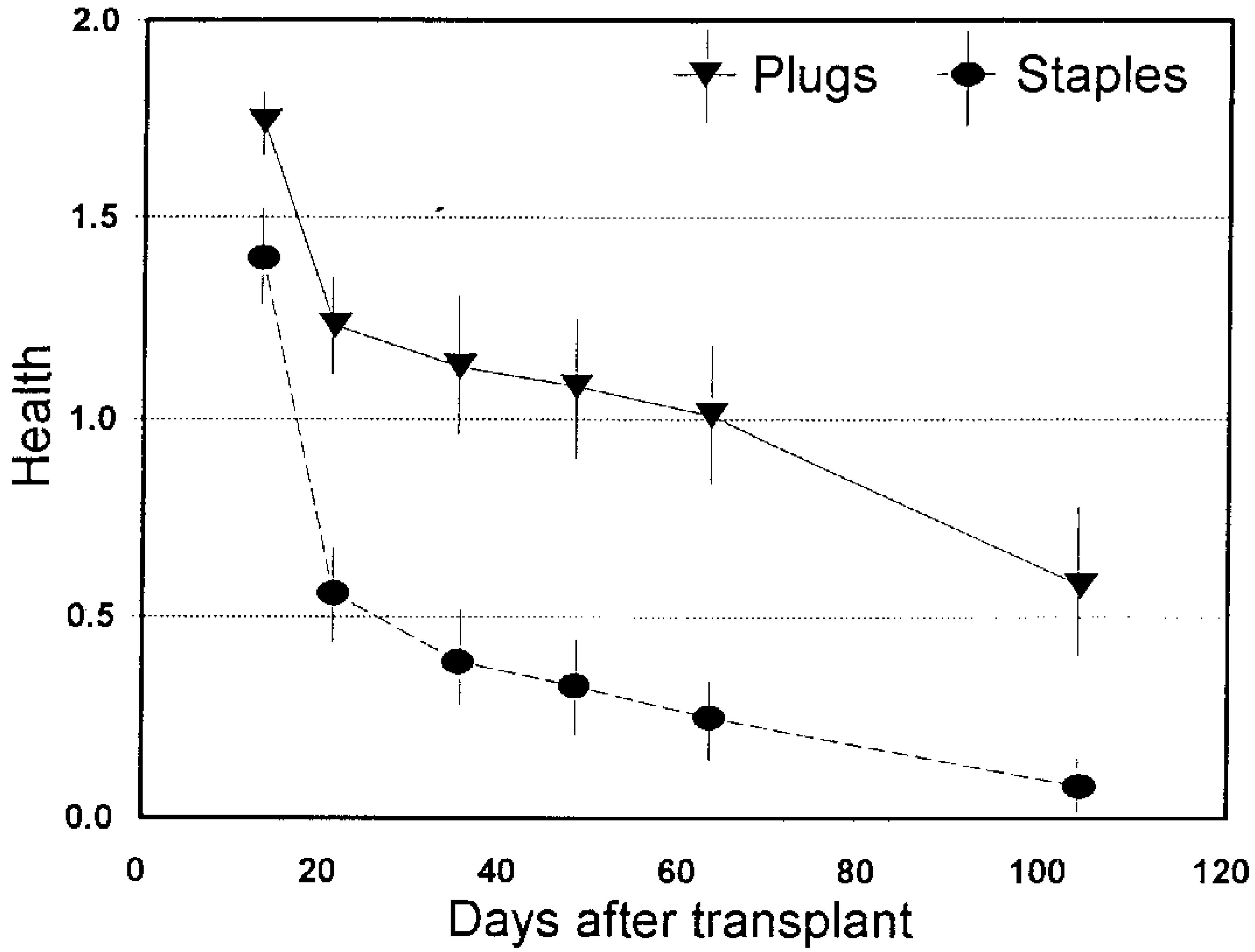

Figure 2. Mean health of *Halodule wrightii* after transplanting by plugs in peat pots or by bare root staples. Maximum health value = 2. Mean health of 9 transplant units per cage was used as the observation. N = 12 cages per method. Vertical bar = ± standard error.

were longer (mean 108 mm) than in sectors containing *Lagodon* (61 mm), *Callinectes* (80 mm), or *Clibanarius* (84 mm). No trend was observed for total number of leaves per TPU among tank sectors. *Halodule* biomass (aboveground plus belowground) appeared to be reduced in *Clibanarius* and *Lagodon* sectors (218 and 219 mg dry weight per TPU, respectively) when compared to *Callinectes* and animal-free sectors (339 and 375 mg dry weight per TPU, respectively). Rhizome growth out of the TPUs was not observed during the test period (20 September - 22 October).

Experiment 3: Halodule versus Ruppia, peat pots versus cheesecloth bags.—Growth rates for *Halodule* and *Ruppia* in peat pot and cheesecloth TPUs were determined by plotting rhizome length against the number of days elapsed since transplanting (Fig. 4). Mean growth rate of *Ruppia* in peat pot TPUs was 5.5 mm/day over 33 days, with a possible increase in growth rate between day 25 and day 33. All 15 *Ruppia* in peat pot TPUs expanded. Mean growth rate of *Ruppia* in

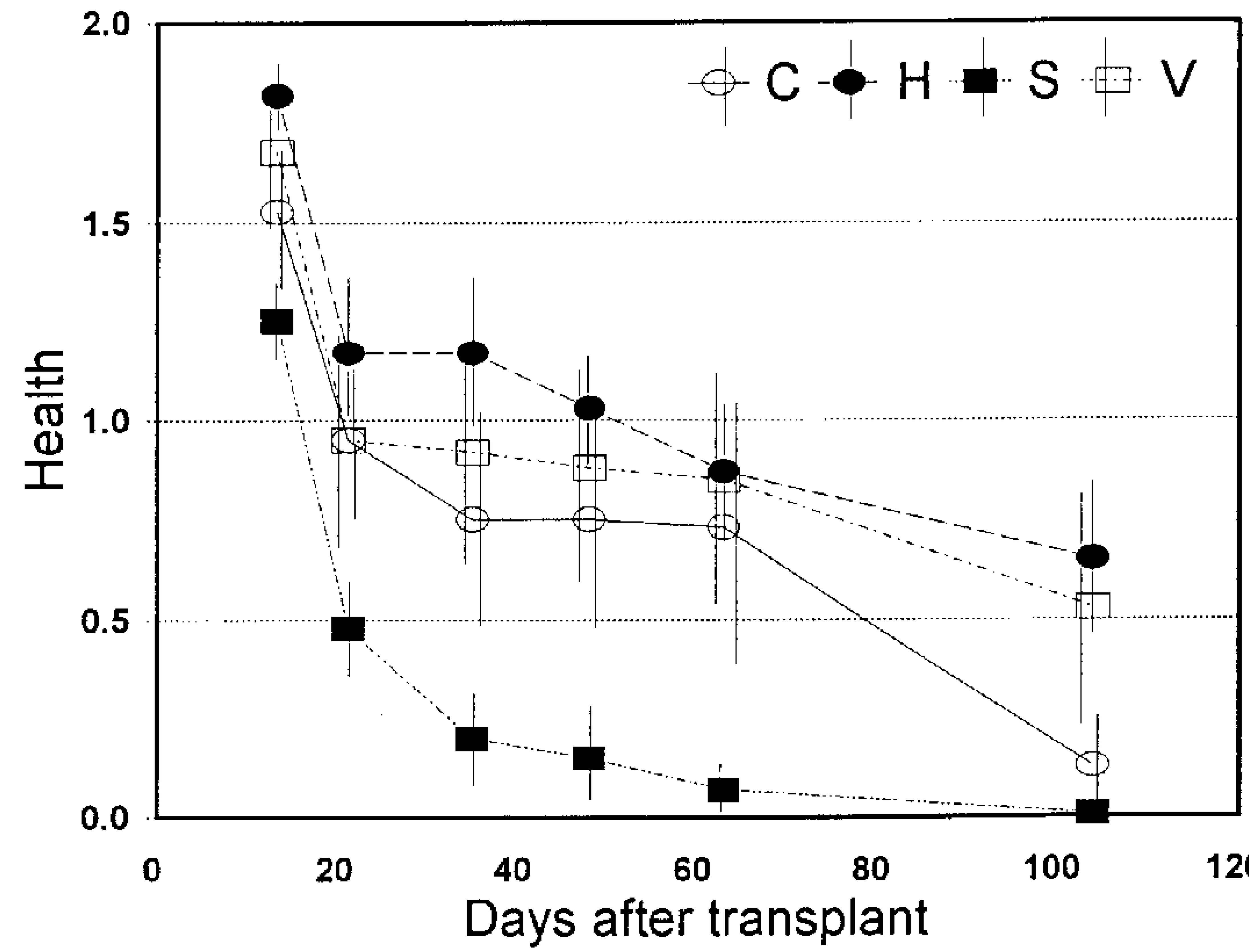

Figure 3. Mean health of *Halodule wrightii* after transplanting into cages of hardware cloth (H; 1.3 cm mesh), vinyl-coated wire (V; 2.8 cm), plastic safety fence (S; 3.8 cm), or chicken wire (C; 5.0 cm). Maximum health value = 2. Mean health of 9 transplant units per cage was used as the observation. N = 6 cages per mesh size. Vertical bar = ± standard error.

cheesecloth TPUs was 3.1 mm/day over 33 days. Ten of the 15 *Ruppia* in cheesecloth TPUs expanded. Mean growth rate of *Halodule* in peat pot TPUs was 1.8 mm/day over the 33-day period, but only six of 15 TPUs showed any expansion. Only one of 15 *Halodule* in cheesecloth TPUs (not figured) grew outside the confines of its container and its mean growth rate was 0.9 mm/day, mostly between days 25 and 33. Excluding the *Halodule* in cheesecloth data, mean rhizome lengths were not significantly different among the three combinations after 25 days (*ANOVA* $F = 1.33$, $P = 0.274$, df = 2,47), but mean length of *Ruppia* rhizomes from peat pots was significantly greater after 33 days (*ANOVA* $F = 7.70$, $P = 0.001$, df = 2,65, GT2 test).

Ruppia in peat pot TPUs exhibited the greatest total coverage (83%) over the 47 day study period, while *Ruppia* in cheesecloth TPUs covered much less area (32%; Figure 5). *Halodule* in peat pot TPUs covered only 5% of the area, and *Halodule* in cheesecloth TPUs (not figured)

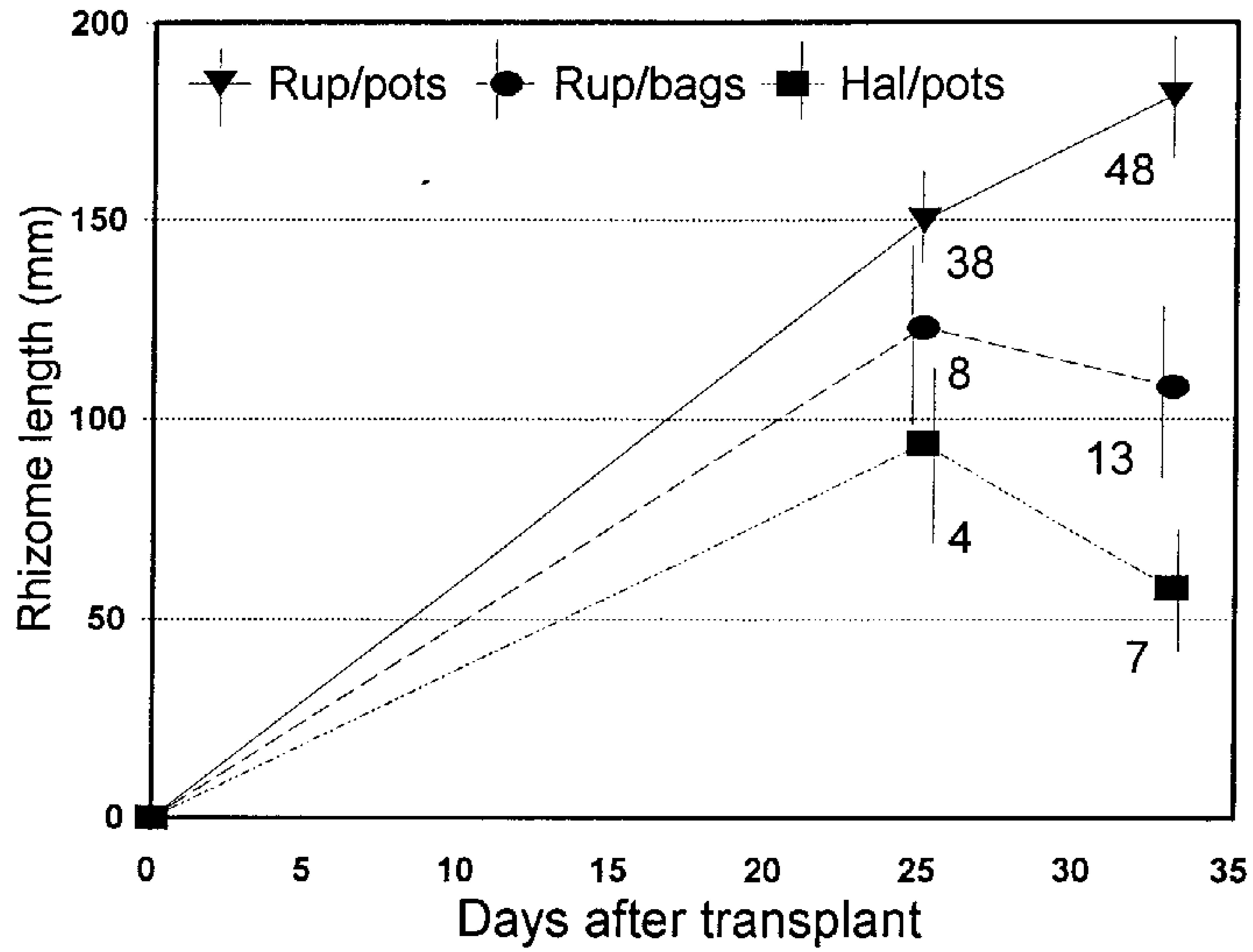

Figure 4. Mean lengths of rhizomes growing from *Ruppia maritima* (Rup) and *Halodule wrightii* (Hal) transplanted in peat pots or cheesecloth bags. *Halodule* in bags not figured. Vertical bar = ± standard error. N = number of rhizomes measured.

exhibited <1% coverage. Many *Ruppia* TPUs had flowered and developed seeds by the end of the experiment (5 November). Mean coverage by *Ruppia* in peat pot TPUs was significantly greater than by other treatments after 25, 33, and 47 days (*ANOVA* $F = 37.35$, 54.92, and 36.32, respectively, $P < 0.001$, df = 3, 56, Ryan's Q test). By day 47, mean coverage by *Ruppia* in cheesecloth TPUs was also significantly higher than by either *Halodule* treatment.

Discussion

Field and laboratory experiments have indicated that submerged aquatic vegetation (*Halodule wrightii* and *Ruppia maritima*) can be successfully transplanted into western Galveston Bay, if certain precautions are taken to insure survival and growth. Factors considered in these experiments were (1) transplant method, (2) type and mesh size of protective fencing, (3) time of the year, and (4) bed configuration.

Transplanting *Halodule* and *Ruppia* using peat pots was more success-

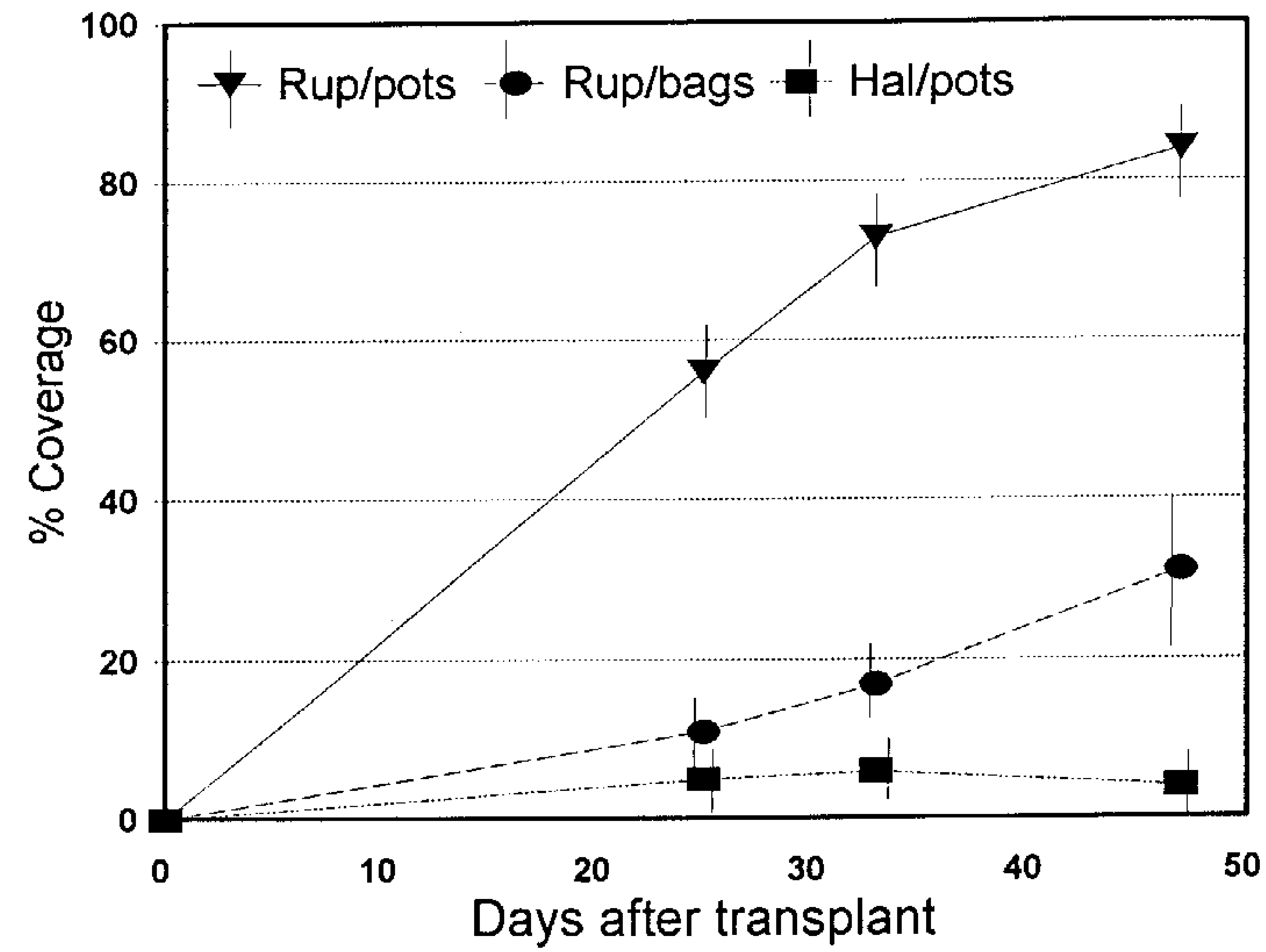

Figure 5. Mean coverage of *Ruppia maritima* (Rup) and *Halodule wrightii* (Hal) transplanted in peat pots or cheesecloth bags. *Halodule* in bags not figured. Vertical bar = ± standard error. N = 15 measurements per type per day.

ful than with bare roots or cheesecloth bags. Although the use of a sod plugger may be stressful to plants, transporting sediment with each TPU likely causes less stress or damage to intact plant biomass than removal of sediments for bare root or cheesecloth methods. The bare root method is not recommended for Galveston Bay since survival was extremely low, even though bare roots have been successful elsewhere (Fonseca 1994; Fonseca et al. 1994). However, trials with the cheesecloth bag method early in the growing season still need to be conducted, since this method is less time consuming at the transplant site. Cheesecloth bags can be distributed by dropping them from a boat or while walking and should remain in place if currents are weak and bioturbators, including wading birds, are excluded (Durako et al. 1993).

Materials used for protective fencing are also important. Health of TPUs enclosed in 1.3 cm and 2.5 cm mesh was nearly always better than TPUs enclosed in 3.8 cm and 5.0 cm mesh. Smaller mesh will exclude a wider size range of herbivores or bioturbators, and cages need only remain in place until transplants are established (60-90 days in this study; 90 days recommended by Fonseca et al. 1994). *Halodule* transplants accessible to typical West Bay macrofauna such as *Clibanarius*, *Callinectes* or *Lagodon* appear to exhibit shorter leaves or lower biomass or both. All three species were observed to sift through the sediment, presumably in search of benthic or epibenthic prey, and thus may have impacted root functions. In addition, *Lagodon* are known to bite tips off seagrass leaves (Stoner 1985). Experimental verification of the validity of these observations, as well as elucidation of mechanisms, still need to be conducted. Smaller mesh sizes probably excluded most bioturbators and may have provided more protection from currents, resulting in better survival of transplants. Mesh material seemed to make no difference in seagrass survival, although plastic mesh or vinyl-coated wire mesh will last longer than uncoated, galvanized wire meshes. Chicken wire (5 cm mesh) is not recommended: it may be useful in excluding rays (Fonseca et al. 1994), but it would be ineffective in excluding many small fishes and decapods common to Galveston Bay and it rusts quickly.

Ruppia transplants grew faster than *Halodule* transplants, at least in the fall. *Ruppia* is found in the relatively high salinity waters of Christmas Bay and in tidal ponds along West Bay, but it is more abundant in fresh and brackish water near river mouths (Adair et al. 1994). In addition, *Ruppia* is an annual and grows back from seeds in the Galveston Bay area, as it does in southern Texas (Dunton 1990). *Ruppia* is a potential tool for brackish and freshwater restorations in Galveston Bay and for mixed plantings with *Halodule*, where *Ruppia* could provide initial stability to a transplanted area due to its faster growth (Dunton 1990). *Halodule* is the plant of choice for higher salinity restorations in West Bay, since it dominates the Christmas Bay seagrass meadows (Adair et al. 1994). *Halodule* transplanted in April and August exhibited survival and growth, while September transplants showed little growth. Thus, *Halodule* should be planted as early in the growing season as possible to allow maximum spread and overwintering potential.

Transplant bed configuration was not clarified. Neither compact beds of dense plantings (0.5 m centers) nor large beds of sparse plantings (1 m centers) could be recommended, nor is it known whether beds should have more or less edge (e.g., a rectangular bed has more edge than a square bed of the same area). In West Bay, dense plantings are

expected to have a better chance of coalescing over the relatively short growing season (April-September) and of resisting effects of currents and bioturbation than sparse plantings.

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